Obtuse AREA EQUILATERAL ACUTE

A FEW WORDS ABOUT MATH

Radius ABSTRACT DESIGN THORAX GENERATE

The nature of math and science vocabulary suggests that we have to think differently about teaching vocabulary in these domains.

Peter J. Fisher and Camille L. Z. Blachowicz

I think I'm an effective math and science teacher. My students are engaged and seem to do well. But I've never really thought much about vocabulary. With these new standards and the push for academic vocabulary, I wonder what I should be doing?

—Veronica, 4th and 5th grade teacher

We often hear comments like this from teachers in our classes and professional learning communities as they're being asked to grapple with the Common Core State Standards and other initiatives that emphasize academic vocabulary as a linchpin of closing the knowledge and achievement gaps.

The new standards call on students to read more complex texts, think critically, and marshal evidence to present what they know, orally and in writing. The standards include a language and vocabulary focus from kindergarten, when students are expected to "describe their physical world using geometric ideas (e.g., shape, orientation, spatial relations) and vocabulary" (National Governors Association Center for Best Practices [NGA] & Council of Chief State School Officers [CCSSO], 2010b, p. 9) through high school, when students are expected to "use precise language, domain-specific vocabulary, and techniques such as metaphor, simile, and analogy to manage the complexity of the topic" (NGA & CCSSO, 2010a, p. 45).

We've spent many years observing, researching, and working in classrooms where academic vocabulary was a focus (Blachowicz, Baumann, Manyak, & Graves, 2013). We've also written extensively about these topics (Blachowicz, Fisher, Ogle, & Watts-Taffe, 2013). Here, we touch on several crucial issues that teachers need to consider as they move toward a new understanding of teaching vocabulary in math and science.

Defining Academic Vocabulary

The Common Core standards distinguish between domain-specific vocabulary—the concepts in a content area (*topic, point on a graph*)—and general academic vocabulary—words that can be applied across content areas (*consist of, analyze*). However, is this a false dichotomy? In an analysis of Averil Coxhead's (2000) academic word list, researchers

ISOSCELES Pi SOLVE Measure Diameter SUMMARIZE EXOSKELETON

AND SCIENCE

COMPARE Energy

(Hyland & Tse, 2007) found little overlap in meaning across different subject areas for supposedly general academic words.

For example, although the word *analyze* shares a common meaning across subject areas—*to resolve or separate a whole into its elements or component parts*—its application differs across standards. In the English language arts standards, students are expected to analyze how the author develops a theme and how specific words shape meaning and tone. In math, to solve problems, students must analyze givens, constraints, and relationships. In science, they must analyze and interpret data as well as alternative explanations and predictions.

Although **math and science terms are complex** and dense, **they're also taught in units** that have semantic coherence.

What does this mean for instruction? Simply put, teachers will need to teach the meaning of words like *analyze* in the context of how those words are applied in a domain and not assume that just because students may have encountered the word in language arts, this understanding will transfer to math and science. The process of analyzing a mathematical problem is not the same as that of analyzing character development.

This is true for many words, whether they're classified as general academic vocabulary or domain-specific vocabulary. They are intertwined, sometimes overlap, and are most effectively taught together. In our work with teachers, we include both categories of words under the umbrella term *academic vocabulary* (Blachowicz, Fisher, et al., 2013).

What's Different About Math and Science Vocabulary?

In math and science instruction, new words typically are more complex, refer to more unfamiliar and complex concepts, and are more densely packed in the text than in the language arts. Concepts are expressed in abstract terms (*solar energy*) and often in phrases (*associative property of addition*). Because abstract terms are more difficult to teach than concrete terms, we need to spend more time teaching them. Science also includes a great deal of classification—another abstraction—so, although teaching the members of a taxonomic class, such as mammals, might be easy, teaching the *nature* of that class can be more difficult.

However, there's a trade-off here. Although math and science terms are complex and dense, they're also taught in units that have semantic coherence. This semantic

FIGURE 1. Problem Sheet for Reinforcing Math Vocabulary

Directions: Using two sheets of 8 ½'' by 11'' paper, construct two cylinders by sticking opposite edges together—one cylinder with a height of 11 inches and one with a height of 8 ½ inches. Which cylinder will have the greater volume, or will the volume be the same?

Prediction ____

Use the table below to describe the steps your group used to solve the problem.

Step	Words	Math Symbols
1	First, we measured the diameter of the base of each cylinder.	D1 = D2 =
2	We then calculated the radius by dividing by 2.	R1 = R2 =
3		

Use the back of the paper for more steps. Be ready to share your solution with the rest of the class.

relatedness provides conceptual pegs for effective teaching and learning. For example, a unit in geometry might have the different types of triangles (isosceles, equilateral, right angle, and so on) as conceptual pegs.

What's Different About Teaching This Vocabulary?

Some aspects of vocabulary and vocabulary instruction differ between the language arts and math and science classes. Let's look at one example. Before starting a lesson on reflex angles—those angles that are greater than 180 degrees but less than 360 degrees—Viktor Carlson reviews some previous lessons:

VIKTOR: We've learned a lot about angles. Let's review—what's one kind of angle?

STUDENT: Acute.

VIKTOR: Show me an acute angle—use your head as the vertex.

[*The students move their arms to show acute angles. The teacher writes on the board, "An acute angle is 'a cute' little angle less than 90 degrees."*]

VIKTOR: What's another kind of angle?

STUDENT: Obtuse.

VIKTOR: With your arms, show me an obtuse angle.

[*Viktor models the angle. One of his arms is parallel to the ground; the other is straight out to the other side, halfway between horizontal and vertical. The students make obtuse angles with their arms, too. The teacher writes on the board, "An obtuse angle is bigger than 90 degrees."*]

VIKTOR: We're missing an angle.

STUDENT: A right angle.

VIKTOR: Show me—using your head as the vertex—that it's 90 degrees.

STUDENT: It's kind of like an *L*. It's a perfect *L*!

The lesson continues with more talk about acute, obtuse, and right angles, and then moves into a discussion of reflex angles. The students use spinners to demonstrate and measure different angles.

This math lesson exemplifies some of the differences between teaching vocabulary in math and science and teaching vocabulary in language arts (and, to some extent, in social studies). The words themselves are different:

- Terms—such as *obtuse* and *reflex*—have specific definitions and can often be visualized through diagrams or physical models.
- Terms can be defined in comparison to other terms in the same domain. Viktor's students understand what acute, obtuse, right, and reflex angles are because they see the similarities and differences among them.

In relation to teaching these terms,

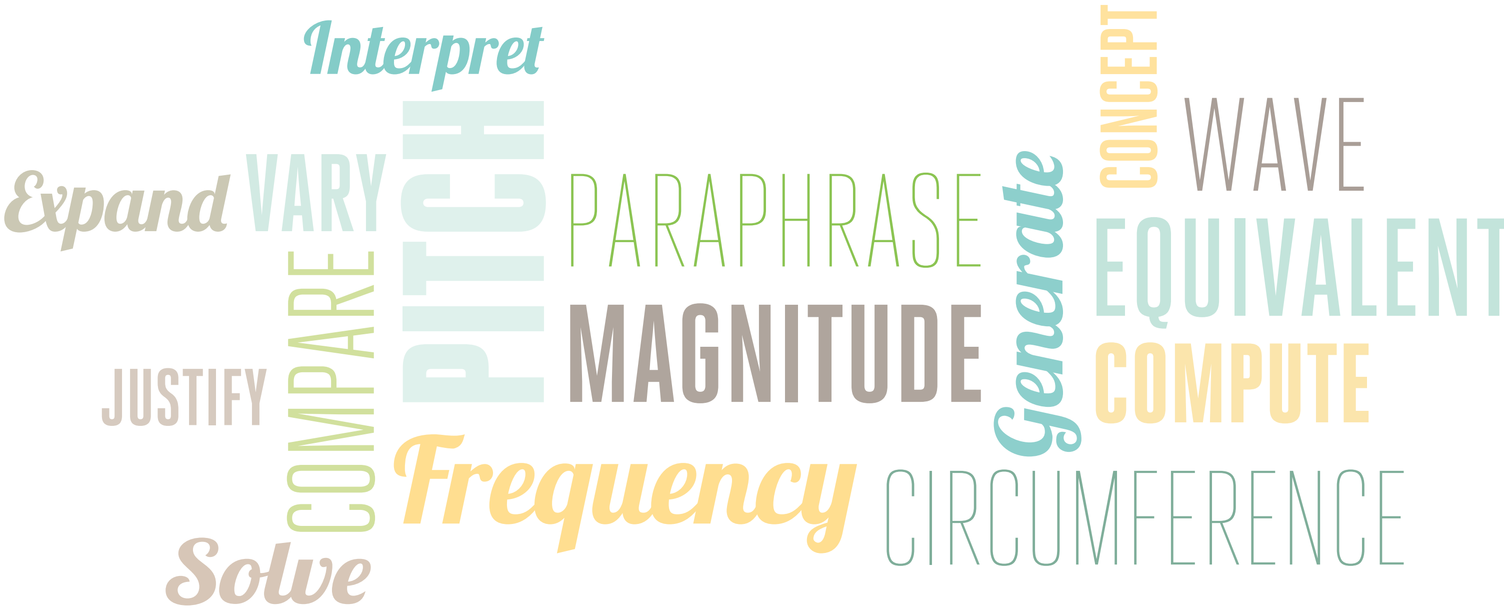
- The teacher revisits concepts several times in a lesson so students repeatedly hear and use the same word in different ways. Viktor reinforced students' understanding of important terms by having them use their bodies to illustrate the different angles, measure various angles using protractors, and use the terms in the discussions that ensued.
- Teaching vocabulary in math and science often involves demonstration and manipulation, especially in the primary and elementary grades.

Four Characteristics of Effective Instruction

These differences point to four ways that teachers can deliver effective academic vocabulary instruction in math and science.

Link Manipulation to Language

Manipulating objects is an important way to explore concepts. However, it's



not just the manipulation of objects and pictures that counts, but also the *talk* about that manipulation that includes the use of important concept words. Problem-solving talk is an essential component of learning academic vocabulary.

For example, in one lesson, students were asked to decide which of two cylinders had the greater volume. They reviewed important terms, such as *diameter, circumference, radius, pi,* and *area of a circle,* as well as the relationships among those terms. Then they worked in groups to complete the problem sheet shown in Figure 1.

Everyone in the group had to agree on and write down the same information. In the column designated "Words," students described in writing the steps they took; in the column designated "Math Symbols," they did the math calculations. The students then shared their solutions with the class using a projection on the interactive whiteboard.

During this lesson, students repeatedly used domain vocabulary, such as *diameter, radius,* and *volume*, as well as more general academic vocabulary, such as *calculate* and *measure,* in their problem-solving talk. The students heard, read, spoke, saw, wrote, and manipulated the words. Linking manipulation to the use of the language is crucial in such learning experiences.

What about word problems? Word problems in math are universal; they ask students to engage in particular kinds of thinking in relation to a text. Here are some of the difficulties that students commonly face:

Because **abstract terms are more difficult to teach than concrete terms**, we need to spend more time teaching them.

1. The supposedly "small" words in word problems can be a challenge—for example, *compare, design, look, work, average, equivalent, vary.*

2. The placement of the main idea in word problems differs from its placement in other texts. For example, consider this problem: "If a rooster is worth five coins, a hen three coins, and three chickens together are worth one coin, how could you buy 100 fowl for 100 coins?" Here, the main idea—what the student needs to do—comes at the end. In typical prose, main ideas come first.

3. The syntax of word problems may be unfamiliar.

4. Students may have difficulty deciding which details are important.

There are several processes that students can use to solve word problems. Fogelberg and colleagues (2008) recommend a bookmark that helps students come up with various strategies. The bookmark might list *read*, *think*, *paraphrase*, *visualize*, *represent*, *solve*, and *explain/justify*—each with a drawing as a reminder.

Reading, thinking, and paraphrasing are self-explanatory. Visualizing refers to imagining the components of the problem in your head. Representing refers to drawing or diagramming the problem. For example, if the word problem is about a bicycle and how far it goes in a certain amount of time, the drawing might involve placing a picture of a bicycle on a timeline. A diagram might include drawing the number of coins involved in a money problem. After students solve the problem, they must explain and justify their results and reasoning.

The various approaches to teaching word problems include different ways of breaking the problem into understandable parts and then representing the process in some way. Any method

will require considerable teacher modeling and practice.

Include Visual Representations

Another common thread in math and science is the interpretation of graphs and charts and other visual representations. Many students are introduced to bar graphs in kindergarten. Learning the specific vocabulary related to graphs comes later and expands across the grade levels. In both math and science, there's a focus on constructing graphs and charts. In other words, students learn by doing.

Talking about science charts can begin early with a strategy called *vocabulary visits* (Blachowicz & Obrochta, 2005), an important component of which is the use of semantic charting and sorting. For example, before a unit on sound, students brainstormed and charted their ideas related to the topic. The chart of one 3rd grader, an English language learner, contained only four words: *noise*, *loud*, *shout*, and *music*. The teacher read aloud Frederick Newman's *Zounds: The Kids' Guide to Sound Making* (Random House, 1983), asking students to listen for words they thought were important. Then students began a word wall, which they added to as their study of sound proceeded. Because this was a two-way immersion class, students added words in both Spanish and English.

Selecting from the growing number of words on the chart, the teacher asked students to decide how to organize these English words into two columns: *volume, high, low, rich, loud, frequency, pitch, intensity, weak, soft.* Working as teams and then jigsawing their team products, students completed this class word sort and presented their charts and evidence from the text. Some students chose words that described volume (*soft, loud*) and words that described pitch (*high, low*) as their two columns. Others chose to use frequency (*intensity, weak, rich*) as one of their columns. Their choices revealed their insights into the relationship of words that describe the characteristics of volume, pitch, and intensity.

At the end of the unit, student teams constructed word clouds (see www.wordle.net) as a final assessment of how many words they now recognized as sound words. The student who had four words in his word cloud at the beginning of the unit had 12 words in his chart by the end of it.

Teaching **vocabulary in math and science often involves demonstration and manipulation,** especially in the primary and elementary grades.

Use Meaningful and Varied Repetition and Review

Repetition is a tricky issue. We know that to learn a word, students must repeatedly experience it in *different* contexts through *varied* instruction. If students didn't understand a word the first time it was taught, repeating the same instruction or having them reread the word in exactly the same context most likely won't be more successful. Front-loading all your vocabulary at the beginning of a unit also doesn't work.

In the following example, you can see how the teacher and students repeatedly use important terms. The focus of this 2nd grade lesson is contrasting insects and spiders. The teacher, Kyra, starts by writing on a chart board, "Who can name the animal groups we have learned so far?" Students offer the following terms: *insects*, *fish*, *felines*, *amphibians*, and *reptiles*.

> Kyra: What does it mean to classify animals?
>
> Student: To put them in groups.
>
> Kyra: Who can tell me about insects? Turn to your neighbor and tell all you know….
>
> Now tell me all you know….
>
> [*Kyra accepts the students' terms—such as* wings *and* antennae*—and draws a concept map on the chart board that shows the different characteristics of insects. She reviews the three body parts—head, thorax, and abdomen—by having the students indicate these parts on their own bodies.*]
>
> Kyra: Insects have an *exoskeleton*—that's a hard outer shell. Open your book to page 32 and look at the pictures of spiders. We'll read a little about spiders and watch a video, and then we'll compare spiders and insects. [*Kyra reads the text and students follow along.*]
>
> Kyra: Turn to your neighbor and tell two things you've learned about spiders.

After watching a video, reviewing what they read, and doing various sorting activities, students work in teams to complete a Venn diagram showing characteristics that spiders and insects do and don't have in common. As a group, they create a class diagram that compares spiders and insects, and they discuss their ideas. Kyra continually has students use and review terms:

> Kyra: Who can use a sentence that tells about both spiders and insects? I'll do one first: "Both spiders and insects are cold-blooded."

STUDENT: "Spiders and insects both have a hard outer skeleton called an *exoskeleton*."

KYRA: Who can use a sentence that contrasts the two? For example, "Spiders spin webs, but insects don't."

STUDENT: "Spiders have eight legs, but insects only have six legs."

This lesson demonstrates a number of important points. First, the teacher introduces and reviews concepts, such as *exoskeleton*, throughout the lesson. She reinforces concepts—such as *thorax*—through manipulation and by using physical examples. Finally, she uses different media—graphics, pictures, videos, and print—to reinforce the concepts taught.

If we look back to the lesson that Viktor taught about angles, we can see some of the same characteristics of instruction. In math in particular, students' knowledge of concepts builds across grades.

Teach Morphemes

Scott and colleagues (Scott, Flinspach, & Vevea, 2011) argue that academic vocabulary instruction in math and science benefits from a generative approach that includes teaching morphemes. A morpheme is the smallest unit of meaning in a language. These can be roots, prefixes, suffixes, or other meaningful parts.

There are several common morphemes in math, such as those dealing with number (*tri, quad, bit*); size (*ampli*, as in amplify; *magn*, as in magnify); and others specific to science (*astro, photo*). Many math and science words—such as *biosphere* and *herbivore*—consist of two morphemes. (For a list of common math and science morphemes, see Blachowicz, Fisher, et al., 2013.)

Two processes can help students develop morphological awareness: decomposing words into their morphemes and deriving complex words by putting morphemes together. In the first, the students look at a word and decompose it to find the root word. For example, referring to a chapter in their science textbook, a teacher might ask students to decompose the word *microscopic* in the heading, "The Microscopic World of Viruses." The teacher could also ask the students to indicate the morphemes by marking them in some way, either drawing a box around them or highlighting them with a highlighter.

The second process—derivation—is harder and is best practiced on words that students are already familiar with. A teacher could give students a list of prefixes and a list of roots and ask them to combine them into words and use those words in a sentence. Building word families and ladders (*photograph, photosynthesis, telephoto, photogenic*, and so on) provides meaningful and enjoyable practice.

Meeting the Challenge

Teaching math and science vocabulary is a challenge. However, by tying the specific features of this vocabulary to rich oral and written language, teachers can produce students who think, write, and speak like mathematicians and scientists—and who will *be* the mathematicians and scientists of the future! EL

EL online

To see an example of a teacher helping English language learners tackle vocabulary in a science text, read the online-only article "Tackling Complex Text with English Language Learners" by Debbie Arechiga at www.ascd.org/el1113arechiga.

Authors' note: All teacher names are pseudonyms.

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